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IRRIGATION



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IRRIGATION



A SKETCH OF
ITS HISTORY AND PRACTICE
IN
VARIOUS COUNTRIES



BY
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Commissioner of Immigration for
Arizona Territory

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THE following papers, with one exception, first appeared in the Arizona "Gazette," and, at the request of many farmers and fruit-growers, they are now presented in pamphlet form. The subject of irrigation has not yet received that attention from the residents of the "dry belt" which its magnitude demands. Yet there is no industrial question of greater importance to the people of Western America; for upon an intelligent mastery of the true principles underlying the control and application of water to the thirsty soil must rest the future growth and prosperity of that region. This is especially true of Arizona, whose grand agricultural possibilities are gradually becoming known and appreciated.

In this sketch I have aimed to present, in a condensed form, all available facts, with the hope that it may serve to dispel some of the dense ignorance that prevails in Arizona on this subject. For much of the data in these papers, I am indebted to Powell's "Lands of the Arid Regions;" the Reports of the State Engineers of California and Colorado; the Report of Hon. A. Deakin to the Governor of Victoria, N. S. W., and the Proceedings of the Riverside Irrigation Convention.

P. H.

PHOENIX, ARIZONA, April 25, 1886.



IRRIGATION.

An Outline of its History in the Old World and the New.

THE cultivation of the soil by the artificial application of water is, without doubt, the oldest system of husbandry known to man. If we accept the Biblical history of the creation, Adam, after that unlucky affair of the apple, was compelled to build irrigating ditches in order to raise a crop on the dry plains of Mesopotamia; and when that ancient mariner, Noah, found himself high and dry after his lengthy cruise, he planted the vine on the sunny slopes of Ararat, and, by means of irrigation, produced the exhilarating beverage which, later on, involved the old patriarch in that awkward escapade so graphically described in sacred history. So that if antiquity be a badge of honor or distinction, this mode of agriculture is certainly entitled to high consideration, for its progress can be traced through all the ages to the times when Adam delved and Eve spun and "gentlemen" were not so numerous as in latter days.

The powerful kingdoms of the ancient world owed all their greatness to the practice of irrigation, and the corner-stones of their prosperity and civilization rested upon this system of tillage. Babylon and Nineveh, whose grandeur and extent is attested by their ruins, derived their wealth and magnificence from the elaborate system of canals which covered the valleys of the Euphrates and the Tigris. Those immense waterways made of that region one of the most fertile countries of the earth—the seat of the learning, the arts, the sciences, and the splendor of the earlier ages. Both the Assyrians and the Medes were an agricultural people, and carried the art of artificial cultivation to a very high degree. Persia, the mightiest monarchy of ancient times, was then, as now, a rainless region, yet irrigation made of it the seat of an empire extending from the Indus to the Hellespont. The pages of history shine with the achievements of this great nation, and the wealth and dazzling magnificence of the courts of Xerxes and Darius is the theme of the historian and the poet. Yet this vast fabric of empire rested upon the canals which brought beauty and verdure to the plains and valleys of Iran. Egypt, the seat of our earliest civilization, the land of religious thought and philosophical research, from which many ancient nations derived their sacred and secular ideas of government, practiced irrigation from the remotest ages. The mighty monuments of that early time, whose ruins are the wonder of our modern world, speak mutely, yet eloquently, of the power and greatness of ancient Egypt. But the whole structure of mental progress and material power were dependent upon the network of canals through the Valley of the Nile. A rich and a goodly land it was—the granary of the ancient world—and, to-day, after constant cultivation for unnumbered ages, this famous valley remains one of the most productive on the globe.

In India and China irrigation has been carried on since man first tilled the soil in those olden lands. The Oriental magnificence of the potentates of historic Hindostan, the

gorgeousness of their courts and the wealth and beauty of their cities, have tempted the cupidity of successive conquerors. The swarming hive of humanity, who dwell in southern Asia, have made of that portion of the globe a veritable garden, solely by the aid of irrigation. Greece and Italy have practiced the art of artificial cultivation ever since Cærops laid the foundation of Athens or Remulus chose the site of the Eternal City. The great cities which flourished around the eastern shores of the Mediterranean, including Carthage, the warlike rival of Rome, fostered and encouraged irrigation, for upon it rested their wealth, their power and their very existence. When the Roman eagles were planted in Gaul and in the Iberian peninsula, the Roman law of waters was made a part of the civil polity of the conquered provinces; and the system of irrigation was perfected and assisted by the establishment of wise regulations and the construction of massive aqueducts, canals and reservoirs. And to this day, the just, equitable and far-seeing enactments of that empire, continue to bear fruit on the fertile plains of Lombardy and Andalusia, and the valleys of Southern France. Thus it will be seen that nearly all the great nations of antiquity rose and flourished in lands where the artificial application of water to the soil was a necessity for the growth of crops. The ruins of dead cities which strew the now desolate regions of Asia Minor, Syria and Northern Africa, were once the centers of wealth and luxury, culture and power. Canals and aqueducts brought beauty and productiveness to the now barren wastes; and dense populations once lived and labored where the jackal's cry is now the only sound that disturbs the ear of the wandering tourist.

IN THE NEW WORLD.

Irrigation was carried on by the semi-civilized races of the new world long before the Genoese explorer sighted the shores of San Salvador. The ancient Mexicans and Peruvians brought the art to a high degree of perfection. When that intrepid soldier of fortune, Cortez, conquered the empire of the Montezumas, he found on the plain of Anahuac a large population, and the country under a high state of cultivation by the aid of numerous irrigating ditches. And when his band of daring adventurers first gazed upon the Valley of Mexico and the Aztec Capital, they were enraptured by the lovely panorama of "green meadows, golden fields and blossoming gardens," while, crossing it in every direction like beautiful silver lace work, the numerous water-courses flashed back the rays of bright sunshine. In Peru, the extensive aqueducts, reservoirs and canals of the Incas astonished the Spanish invaders. Such strong and costly irrigating works no nation of ancient or modern times ever constructed. But earlier than the records of authentic history irrigation was practiced by unknown races on the Pacific Coast of the western world; and the traces of artificial water-courses which Coronado encountered in his expedition through Arizona, in 1540, would show that this system of agriculture dates from pre-historic times in the new continent.

With the admission of Texas to the Union, begins the history of irrigation in the United States. The acquisition of California and New Mexico, later on, largely increased the irrigable territory, but Americans did not engage in it to any great extent until the settlement of the Mormons in the Valley of Salt Lake. They found there a barren desert and have transformed it into a blooming garden. Few people have any idea of the vast territory within the boundaries of the republic that is entirely dependent upon this method of agriculture for the production of crops. According to Maj. Powell, the "arid region" extends from the 100th meridian to the Coast Range, and from the boundary of British America to the line of Mexico, being 1500 miles in its widest part, from east to west, and over 1000 miles from north to south. This vast area contains more than 1,000,000 square miles, or 640,000,000 acres—being nearly one third of the whole Union. It is five times larger than France, and more than fourteen times greater than Great Britain and Ireland. Nearly one half of Kansas and Nebraska, one third of Texas and Oregon, three fifths of California, the whole of Colorado and Nevada, nearly half of Dakota, a third of Washington Territory, together with the whole of Wyoming, New Mexico, Utah, Montana, Idaho and Arizona, are embraced within the "arid region" and must rely

mainly upon irrigation for permanent progress and prosperity. Of this vast territory it is estimated that not more than four or five per cent can ever be reclaimed and made productive.

During the last ten or fifteen years this method of tillage has made rapid strides in the United States. It is estimated there are over 2,500,000 acres now cultivated in this way, and the total length of the canals within the dry belt is put at 12,000 miles. In the State of California alone, the value of irrigated lands and works is nearly \$200,000,000, while the value of its yearly product from irrigated vineyards and orchards is more than \$15,000,000. Colorado has over 1,000,000 acres watered by irrigating ditches, and the value of the crops raised in 1884 was over \$7,000,000. In Utah there are nearly 700 miles of canals costing \$2,500,000 and 650,000 acres under tillage. No reliable data on the subject can be had from New Mexico, but it is believed its cultivated acreage will not fall short of Utah. Nevada is credited with having 80,000 acres watered by 800 miles of canals, while western Kansas has over 300 miles of main irrigating ditches, costing half a million of dollars and reclaiming 600,000 acres. These figures will convey some idea of the magnitude and importance which the irrigating system has already attained in the United States. And the efforts at reclamation thus far may be considered as little more than tentative. Our knowledge of this system of agriculture is yet crude and imperfect, but with that marvelous adaptation to surrounding conditions, so marked a trait of the American character, it is safe to predict that another quarter of a century will see a larger area reclaimed and a more perfect water system in western America than in any other portion of the globe.

Although the United States cannot show such massive and enduring irrigation works as India, Italy, or Spain, yet marked progress in this branch of engineering is seen within the last half dozen years. Among the States and Territories of the arid belt, Colorado is entitled to first place for the most substantial and elaborate system of artificial waterways. Some of those deserve mention here. The weir of the South Platte Canal is 120 feet long, from the cliff on one side to its waste gate of solid masonry, 24 feet wide, on the other. By means of a frame work of timbers, 12x12, which are bolted to the bedrock, filled and planked on the face with six-inch pieces, it raises the water to the level of a 600 foot tunnel. This tunnel is 20 feet high, 16 feet wide, hewn out of solid rock at a cost of \$60,000. After passing through the tunnel the water enters a flume 2,640 feet in length, 28 feet wide and 7 feet deep, which cost \$100,000. The waste gate and head gate are protected by a substantial boom 75 feet in length, built of 12x12 timbers. These admit the water through bars below the surface, and protect the works from floating trees during high floods. This canal is 100 miles long. The weir across the North Poudre is a fine piece of engineering skill and has withstood some of the fiercest of Rocky Mountain floods. It crosses a deep gorge, 160 feet wide from wall to wall, and is in the form of an arch bending up stream. The upper part is composed of cribs filled with stones, while the lower face is formed of three steps of solid masonry so keyed into each other that the pressure wedges them the more firmly. This canal has a mile of flumes, and the cost of constructing its first mile was \$50,000.

A large amount of capital has been invested in irrigating enterprises in California, but, owing to different conditions, the weirs and head gates do not demand such a costly outlay as those of Colorado. The Merced Canal, now under construction, will be 100 miles long and will reclaim 300,000 acres at a cost of \$1,000,000. This great ditch passes through one tunnel 1,600 feet in length, solid rock. The San Joaquin and Kings River Canal is 78 miles long, and 60 feet wide. The "76" Canal in Fresno County is 50 miles long, with a width of 50 feet. At Pasadena the water is carried from the source of supply by 700 feet of fluming, thence through an iron pipe, three miles long and 12 inches in diameter, to a cemented reservoir. From this reservoir pipes convey it to the land to be irrigated. At Redlands, San Bernardino County, there are six miles of iron piping, while at Ontario \$50,000 has been spent on a tunnel to develop water. The Dodge City Canal, in Western Kansas, is 90 miles long and 50 feet wide, while the "Great Eastern," in the same State, has a length of 60 miles, with a width of 40 feet. The largest irrigation head work in the United States is that of the Eureka

Canal, in Kansas. It is 1500 feet long, 10 feet high and diverts five feet of water through the banks of the Arkansas into a canal 30 feet wide at the bottom, and 80 miles in length.

The outlay on some canal enterprises has been large. The San Joaquin Valley waterway cost \$1,300,000; the South Platte Canal, \$750,000; the North Poudre, \$250,000; the Salt Lake ditch about the same, while in India it is claimed that the British government has expended over \$100,000,000 for this purpose.

Reservoirs for the catchment and storage of water have been in use from the remotest times in all irrigating countries. Massive and costly works of this character are found in Spain, Italy, Central Asia, Persia, India, Northern Africa, Mexico and in South America. Although but of recent origin in the United States, their benefits have already been demonstrated and their number is rapidly increasing. In Colorado, several canal companies are adding a chain of such reservoirs as an adjunct to their water supply. The largest is connected with the Big Thompson Canal, and covers four hundred and fifty acres to a depth of thirty-five feet, twenty-one feet of which is available. This is sufficient to water 12,000 acres. The largest reservoir now in use in the United States, is in Bear Valley, California, where a wall of strong masonry three hundred feet long and sixty feet high holds 8,000,000,000 gallons of water. This inland lake will give a continuous stream of one hundred and fifty cubic feet per second, for one hundred days, sufficient to supply 50,000 acres. The cost of the work was \$60,000. There is a project now on foot in Colorado, for the construction of an immense reservoir in the foothills of the Rockies. It will have a storage capacity sufficient for the supply of 100,000 acres, and will be tapped by a canal eighty miles long and seven feet deep.

This fragmentary outline may help to give a faint idea of the magnitude and importance of this system of agriculture. To-day, nearly one-half of the human race depend upon it for existence. For the people of Arizona, it is a question of vital interest. The future growth and permanent prosperity of our territory depends mainly upon the successful solution of the irrigating problem in the valleys of Southern Arizona.



THE "DUTY" AND COST OF WATER.

WHAT is known as the "duty" of water is that certain quantity required to produce a crop on a given area of land. This quantity varies in different countries, owing to climatic conditions, the nature of the soil and the kind of crop. On the plains of Lombardy it is estimated that one cubic foot of water flowing per second, will irrigate 90 acres; in France, 100 acres; in India, from 150 to 400 acres; in Algeria, from 300 to 400 acres, in Spain, as high as 1,000 acres. At Pasadena, California, the duty of one cubic foot of water reaches 1,665 acres; while at Lugonia, in the same State, by means of sub-irrigation, 8,000 acres have been made productive. At Sierra Madre, 580 acres are cultivated by this quantity of water; at Ontario and Redlands, 400 acres; Los Angeles and Anaheim, 200 acres; at Riverside, 300 acres; at Fresno, 160 acres; in Utah, from 100 to 150 acres, and in Colorado, from 80 to 150 acres. In the older irrigating countries the unit of water measurement is the flow of a cubic foot per second. This is a reliable and definite standard; but in nearly all the irrigated regions of the United

States, the "miner's inch" is the unit generally used. This mode of measuring water is a legacy of the early mining days of the Pacific Coast. It is as variable and unreliable as the Roman pace, and according to Mr. Hall, State Engineer of California, is an "indefinite quantity." It varies with the altitude and the temperature of the water all the way from 1,670 cubic feet to 2,680 cubic feet in twenty-four hours. At Columbia Hill, in California, a series of experiments showed that a miner's inch, under a six-inch pressure, discharged 2,267 cubic feet in twenty-four hours, while at North Bloomfield, same State, the results with the same pressure were 2,159 cubic feet, in twenty-four hours. These figures show how variable and uncertain is this measurement, and how difficult it is to determine the exact duty of water in countries where the system maintains. In California, the miner's inch is generally the discharge under a four-inch pressure, while in Colorado, the pressure established by law is six inches. This would give about fifty miner's inches to the cubic foot in the former State, and about forty in the latter. The State engineers of both commonwealths have urged the adoption of the cubic foot as the standard unit, and doubtless their recommendations will be incorporated in the laws of their respective States.

The quantity of water required to produce a crop on a given area, varies with the nature of the soil. A coarse, sandy and porous soil will sometimes take ten times the quantity requisite for heavy clay or adobe. With a compact and solid soil the floodings should be light and frequent, while with that of a more porous nature, they should be heavier but given at longer intervals. What is known as "capillary attraction" exerts a marked influence on the irrigation of some soils.

CAPILLARY ATTRACTION.

The principle may be illustrated by placing a tube of glass, whose bore will admit a single hair and open at both ends, vertically, in a basin of water, with the lower end immersed. The water is observed to rise and stand within the tube at a higher level than the water outside. This action of water is known as capillary attraction. Another common illustration of the principle is shown by suspending a towel so that its lower end rests in water; in a short time the water will rise in the meshes of the towel to a *certain height* but no higher. And so a stratum of earth whose base rests in water, will take up the liquid to a *certain height*—no farther. If two tubes of glass be used and one has a smaller bore than the other, the water in the smaller will rise to the greater height. And so it is in soils of different texture—the water will rise to the greatest height in the finest grained. On heavy, alluvial soils, capillary attraction is much greater and the water will rise higher than in that which is loose and sandy. It is supposed that heat has considerable influence on this action of water. In California and in other countries with a high summer temperature, it is much greater than in Colorado and regions with a severe winter climate.

NATURE OF CROPS AND LAND.

The duty of water is also very materially affected by the nature of the crops. Small grains and grasses require much more than fruits. In Colorado, where grain is the principal crop, there is a lavish use of water, the average depth of the floodings during the season being fourteen inches. Over-irrigation is practiced in that State very generally, and its injurious effects are shown by the "rust" which very often attacks the crop. In the fruit-growing regions of Southern California, from six to ten acres are now cultivated by an inch of water. Oranges are watered three or four times during the summer. Vines require two or three irrigations during the first year. It is well known that the roots of this plant will penetrate ten or twelve feet, and if moisture is encountered at that depth, they need no surface irrigation. Careful handling of the water can do wonders, and in portions of California, where sub-irrigation prevails, the duty of water has been increased twenty-fold. Winter flooding is also found to effect a large saving, and the plan is now generally followed where cereals are the principal crop.

The quantity of water required for new land is much greater than for that which has been under continuous cultivation. Therefore the duty of water is greater in old irrigating countries than in new. When the Mormons first settled at Salt Lake, there was only sufficient water to cultivate 800 acres from a certain source, while to-day, from the same source, 5,000 acres are made productive. In the Mormon Colony of Bountiful, where at first only a few families could live, there are now nearly 4,000 people, and with the same water supply. Continuous irrigation closes the pores of the soil with an infiltration of rich silt, so that it absorbs more slowly and retains the moisture much longer. But too much water makes the land cold, injures crops, and eventually destroys the productive capacity of the soil. This practice of over-irrigation is followed in nearly every portion of the United States where artificial cultivation is carried on. Competent authority has said "there is six times too much water used in Colorado, and four times too much in California." The injurious effects of overflowing is seen in the rust in grain, and the insipid quality of fruit.

OVERFLOODING.

The experience of the Fresno Colony, in California, is a striking example of excessive saturation. Fifteen years ago the place was a desert, and water could not be reached at a less depth than forty, and from that to eighty feet. The first canal taken out, with a capacity of 20,000 inches, was so greedily drank up by the thirsty soil that it had nearly all disappeared before it reached the small area brought under cultivation. To-day, there are fifteen canals drawing their supply from the same source—Kings River—with a cultivated area of more than 60,000 acres. Water can now be struck anywhere on the plain, at a depth of ten feet, and in many places at six feet. The soil has taken up the water like a sponge, until it can hold no more. The once "arid region" is thoroughly saturated, and irrigation by "flooding" has, in many instances, been abandoned, the "seepage" being all sufficient to raise a crop on many farms and vineyards. Where once the competition for water was keen, suits are now being brought against canal companies for excessive saturation; and in the midst of the once parched plain there are patches of artificial morass from over-irrigation! One of the largest vineyards has not been watered in two years, and the owner has actually been compelled to dig ditches to a depth of six feet to drain his land! There is a wide difference in the quantity of water which two neighbors, having exactly the same soils, will use during the season. One will require three times as much as the other; but the best results are obtained in all lands by the use of the least quantity of water; and it is also a fact well established by experience, that soils carefully cultivated take much less water than those which are neglected.

The loss by evaporation and absorption is very large, and presents another difficulty in determining the duty of water. The present system of loose, open waterways, which prevails in the United States, is a most wasteful one, entailing a loss of from twenty-five to fifty per cent, and sometimes much greater. A canal in the San Joaquin Valley took in ninety cubic feet at its head and delivered only fourteen cubic feet, twenty-eight miles away! The lateral ditches increase this loss and the farmer only receives a small portion of what he pays for. Under the present system it is believed that fully one-half the water taken out is lost before it reaches the irrigator. Too many canals are mainly the cause of this great loss. In the San Joaquin Valley there are thirty-two ditches, where eight would be sufficient; and at Fresno there are half a dozen where two would be enough. A careful examination of two of these canals by the State Engineer showed that the water could be carried in one, at a saving of twenty per cent.

ITALIAN METHOD.

The highest duty of water is perhaps developed by the Italian Method, which is now practiced in parts of Utah. This is secured by the hour rotation, or time system of distribution, which is more clearly explained by the following table. By this method it is estimated that the capacity of a canal is fully doubled over what it would be by the all-at-one-time plan.

*Hourly Distribution Table for the Year of the Water of the Ditch, carrying
 Cubic Feet per Second, of which the Period of Rotation is
 Eight Natural Days or 192 Hours.*

Number.	Name of Irrigators.	Commencement of Horary Distribution.		Termination of Horary Distribution.		No. of Hours Each.
		Hour.	Day.	Hour.	Day.	
1	A	4 a.m.	April 1.	6 p.m.	April 1.	14
2	B	6 p.m.	April 1.	10 a.m.	April 2.	16
3	C	10 a.m.	April 2.	10 a.m.	April 3.	24
4	D	10 a.m.	April 3.	4 a.m.	April 4.	18
5	E	4 a.m.	April 4.	6 a.m.	April 4.	2
6	F	6 a.m.	April 4.	7 a.m.	April 5.	25
7	G	7 a.m.	April 5.	1 p.m.	April 6.	30
8	H	1 p.m.	April 6.	12 m.	April 7.	23
9	I	12 m.	April 7.	7 a.m.	April 8.	19
10	K	7 a.m.	April 8.	4 a.m.	April 9.	21
		Total.	192

Rotation then commences the same.

This table also serves as an agreement when signed by the parties in interest. The system has been practiced in Italy for hundreds of years, and is an example of rigid economy in the use of water.

COST OF WATER.

The cost of the quantity of water required to raise a crop is an important consideration for the owner of the land. Whether he constructs his own ditch or purchases from a corporation, the outlay on the acreage reclaimed is a steady tariff on his yearly product. Originally, under the co-operative plan of canal construction, where the owners of the lands to be benefited joined their labor and capital, the cost of the water to each depended mainly upon the first outlay for the building of the works and the yearly expenditure for repairs. But as the land continued to be cultivated and valuable crops raised, the price of water largely increased. The value of "water rights" grew in value, and those who desired to purchase from the original owner had to pay a round sum in advance of the actual cost.

Where large waterways have been constructed by united capital, the price of water to the consumer is often a heavy and sometimes an arbitrary tax, levied without regard to the actual amount of money expended for the completion of the works, or an equitable return of interest on the investment. It is where instances of such unjust and oppressive charges have been made by canal corporations that the law has been invoked to protect the cultivator; for it is held, and with good reason, that if the State has the power to regulate railroad tariffs, it has also the power to prevent excessive and exorbitant charges for water. And no doubt its right to regulate the control of water is as truly inherent in its sovereignty as is its unquestioned power to legislate on land. For in reality, in irrigated countries the true standard of value is the water, without it the land is almost worthless.

In Colorado, which should be a model for all, it has been estimated that the cost of canal construction is from \$5 to \$6.25 per acre, of the area to be irrigated. In Kansas, where the conditions for building are more favorable, irrigation works have not cost more than \$2.50 per acre, of the land brought under cultivation. Again, where extra work,

such as tunneling, fluming, etc., has to be met, or expensive piping, as at Pasadena or the Highland Canal, in Los Angeles County, the course of construction may reach from \$40 to \$50 per acre. The fact has been demonstrated that the greater the area to be served by water, the less will be the cost per acre for the construction of works. The 150,000 acres at Bakersfield are watered at the rate of \$2.50 per acre. The "76" canal, at Fresno, supplies 20,000 acres at a cost of about \$6 per acre; but if completed according to the original plan—to reclaim 180,000 acres—the cost per acre will be less than \$4.

The price for "water rights" in the small colonies of Southern California, is much higher than in any other part of the irrigable regions of Western America. At Ontario, Pomona and Etiwanda, a "water right" costs from \$75 to \$100 per acre; and as one-tenth of a miner's inch is the allowance for an acre, it will be understood how precious the fluid is where the supply is limited. In Colorado, where large irrigation enterprises are the rule, 80 acres are supplied for \$20, and in Utah for \$12.50, while in Kansas a "right" for the same acreage is much less.

Having secured a "water right" the cultivator is then subject to a yearly assessment for maintenance. This is the general rule in all the States and Territories of the arid belt. This ranges from \$2 per acre in Kansas to fifty cents in the smaller California colonies. In Colorado the maximum rate is \$1.50 per acre; in Utah it is \$1, and sixty cents in Fresno. In portions of California there has been much contention about the price of water. Canal corporations have been inclined to make exorbitant charges, but the law giving the Boards of Supervisors power to fix rates has, to a great extent, regulated the vexed question. The prices are now set with the view of allowing water companies a fair interest on their investment. At Los Angeles water is sold by what is called a "head," which varies, under loose measurement, from two to four cubic feet per second. The cost of this quantity to the consumer is \$2 per day or \$1.50 per night within the city limits, and twice this price outside the municipality. At Riverside the cost is about \$3 for a cubic foot for twenty-four hours. The prices of "water rights" vary from causes other than those named, and a most important one is, whether the owner of the water has land of his own to sell with it. But one main cause of increase in price is the value of the crops which the land produces.

IN COLORADO AND CALIFORNIA.

At the formation of the Greely Colony, Colorado, 80 acres, with "water right," could be purchased for \$300; to-day, the same "right" is worth \$1,000, while the land cannot be bought for less than \$3,000. Water in Southern California has risen rapidly in value during the last five years, but as it is generally linked to the land, it is difficult to determine the exact price that is paid for it—though in reality water is what the purchaser gives his money for. Land in that region which in its wild state would not bring \$5 per acre, is considered worth from \$50 to \$75 when under a ditch. A study of the "capital value" of water in California, will give an idea of its importance. It has been estimated that a flow of a cubic foot per second, for the irrigating season of all future years, is worth from \$75 to \$125 in grain land, and \$150 in fruit land. This is the price to apply such a stream to a special piece of land as long as the irrigator may think necessary—the knowledge that an excess will ruin his crops being the only limit. But if a flow of a cubic foot per second were bought in perpetuity without any limit to the acreage to which it might be applied, or the time or circumstances of applying it, the capital value of such a stream in Southern California to-day, would be \$40,000, or \$1,000 per inch. This is the calculation of Hon. Alfred Deakin, of Australia, who has given the subject much study. The price of water in the irrigated regions of the Old World, differ as widely as in the New. The average cost of rented water in the dry regions of the United States is from \$2.50 to \$6 per acre, while in France it is \$7 per acre. In Italy the yearly rental of water is from \$2 to \$3 per acre. The highest figures can be paid when the land is devoted to the cultivation of valuable fruits, such as oranges, limes, olives, raisin grapes, etc., but the farmer who grows cereals must have cheap water if he hopes to realize any profit.

ECONOMY IN ITS USE.

Irrigation is an art which must be learned by experience, and a thorough knowledge of local conditions. Its history in all lands shows that where water is scarce, and consequently dear, the greater is the "duty" it performs and the more lucrative the return which the farmer receives from the soil. When the supply is limited and the price high, the irrigator hoards every drop, and takes only what is absolutely required for the production of a crop; but where water is plentiful, and the laws regulating its control and supply are vague and undetermined, the conditions are reversed, and there is waste and extravagance. This is an important matter which every farmer on irrigated lands would do well to study. Careful handling of water and economy in its use means a saving in its cost, and an extension of the irrigable area. When one half or one third of the quantity now used in most of the dry regions of the West is found amply sufficient for the growth of a crop, it will not only be a gain to the farmer, but it will double and treble the productive area, and make homes for thousands on the now barren wastes. On this subject the State Engineer of Colorado remarks that many of the canal companies in that State make contracts for water which are detrimental to the best interests of the commonwealth, inasmuch as no inducement is held out to the purchasers to use it with economy. He recommends that contracts for water should be for absolute quantities, and then if the cultivator can farm with less, by skill and care in the handling of the fluid, the value of his surplus, which can be sold to those who need it, should be placed to his credit.

The artificial system of tillage in the United States is yet in its crude state, and our rough ditches and brush wingdams are only a slight improvement on the simple water-wheel of the Egyptian *fellah*. But with the cemented canals, the massive aqueducts and reservoirs of Spain and Italy, the duty of water will be largely increased, and its cost correspondingly diminished in the arid regions of the Republic.



THE LAWS OF WATER.

THE "law of waters" is the most difficult and complicated of all the questions relating to irrigation. The control and equitable distribution of an element so shifting and variable has been the study of some of the ablest statesmen and economists of the Old World. And while the "land question" is now recognized as the leading social problem of the age, that of water is of no less importance to a large number of the human family. Throughout the arid belt of the United States it may be said that custom and usage mainly govern. Beyond a general proposition that water is public property to be used for the public benefit, the government has no clear-cut and well-defined enactments upon this important subject. The exception is the Act of Congress, of 1866, which recognizes the right of appropriation, for mining, agriculture, or other useful purposes. But the common law of England, which has been engrafted on the jurisprudence of the United States, recognizes and maintains the doctrine of "riparian rights," and it is the law of every State in the Union, with one exception. Divested of legal verbiage, this doctrine virtually means that a riparian owner is entitled to receive from the proprietor above him, and must transmit to his neighbor below, the waters of the stream upon which his land abuts, undiminished in volume and unimpaired in quality.

THE RIPARIAN LAW.

To put it more clearly: Suppose a man owns the land on both sides of a stream, *at its mouth*; under the application of the law of riparian rights, he would be entitled to receive the entire volume of water in the stream, undiminished or unimpaired. It will be readily seen that the recognition and enforcement of such a law is destructive to irrigation. It virtually ignores the right of appropriation and would prevent all cultivation by the artificial application of water. Such a law may be entirely in harmony with existing conditions in England and the nations of Northern Europe where irrigation is hardly known, but it is altogether inapplicable to the rainless regions of Western America, to Southern Europe, and to a large portion of Asia, Africa and Australia; yet, this is the law recognized by the courts in every State, except Colorado, and whose absurd provisions have done so much to retard the development of the irrigable belt and caused so much expensive litigation.

In all lands and in all ages since the establishment of organized society, the supreme governing power has exercised sovereignty over water, declaring it to be public property for the uses and benefit of the people. This was the Roman law which was introduced and enforced in the conquered colonies of that empire where irrigation was practiced. The Roman law distinctly recognized the right of "appropriation" for agricultural purposes, and among the Latin nations of Southern Europe that right maintains to-day.

LAWS OF THE OLD WORLD.

The Spanish "law of water" is an elaborate and exhaustive compendium. The waters of the kingdom are under administrative control, and appropriations can only be made after due examination by the authorities. The Spanish law distinguishes between waters on private and public lands, the former being under the control of the owner of the land, under certain restrictions, and the latter the property of the kingdom. The water is held by the Government for the use of the people; its control and distribution is regulated by local and general laws. No one is permitted to appropriate more than he actually requires, and no diversion can be made from a stream unless the matter is thoroughly examined by the water commissioners, and its effect on prior appropriators clearly shown. There is no such thing as unlicensed diversion or appropriation of the public waters, and no waste or extravagance is permitted in their use. Similar laws prevail in France, Italy and Algeria. There is a complete and thorough administrative system in all those countries, and a man can no more appropriate and convert to his own use large quantities of water than he can large bodies of land. The jurisdiction of the State over the former, and the laws regulating its use and defining its ownership, are as comprehensive as those relating to the latter. In India, the entire system of waterways and works is under control of the Government, and the laws and usages controlling its appropriation and distribution are as perfect as the experience of centuries can make them.

The miner's customs of the early days in California are the foundation for almost all the legislation on water which at present exists in the arid regions of the West. Except in the Pueblo settlements of New Mexico, where the communal laws of the Aztecs still prevail, our ideas of the appropriation and use of water are derived from the flumes and ditches of the placer miner. In California, so conflicting are the decisions of courts and legislative enactments, that the "laws of water" in that State are in a very unsettled condition. The State Constitution defines water as "public property;" but the common law of England, so far as the same is not repugnant or inconsistent with the Constitution of the United States, has been incorporated in the Civil Code. This virtually recognizes and establishes the riparian doctrine, and has been so decided by the Supreme Court of the State. This decision, in direct opposition to the doctrine of "appropriation," has been appealed to the Supreme Court of the United States, but pending a final judgment, the lower courts are filled with litigation.

IN CALIFORNIA.

There is hardly a doubt that the opinion of the highest tribunal will be against the enforcement of the riparian law within the arid belt of the West. The right to divert water for irrigating purposes, has been recognized on the Pacific Coast for more than one hundred years, under the laws of Spain and Mexico, and by the state and national governments. For more than twenty years after the acquisition of California, the law of riparian rights was not heard of. The legislation of Congress is in harmony with the law of appropriation; and the Supreme Court has heretofore decided that "the rights of miners who have taken possession and worked said mines, and the rights of persons who have constructed canals for purposes of 'agricultural irrigation,' in the region where such artificial use of water was an absolute necessity, are rights which the government had recognized and encouraged, and was bound to respect." Public opinion, and the ablest jurists of the State are against the riparian doctrine. Its enforcement would be a virtual recognition of a private ownership in an elemental source of wealth, and in direct opposition to the fundamental law of the State, which declares that "water is a public use."

What is known as the "Satherwhite law," passed by the legislature of 1876, guarantees the water as a "perpetual easement" to the land. This law welds together the land and the water, and forever sets at rest the right of the irrigator to his water supply. Next is the "Streeter law" of 1881, which places the regulation of water rates in the hands of the governing powers of counties and municipal corporations. In Los Angeles, the water supply is under control of the city government, who maintain the ditches, and sell the water to those who require it. Beyond this, there is no legislative control or regulation of the public waters by the State of California. With the issue between the riparian proprietor and the appropriator still undecided, the question is in a chaotic condition; and as the Governor has pertinently stated, "the rights to the use of water are undefined and unproven claims." The laws of Nevada relating to water, are even more indefinite and contradictory than those of California. Following the precedent set by the latter State, the Supreme Court of the Sage-brush commonwealth, upholds the doctrine of riparian rights, and, as a result, litigation about water is of frequent occurrence. In Utah and New Mexico, the territorial legislatures have no enactments regarding public waters, but the right of appropriation for agricultural purposes is recognized in both. In Salt Lake City, the water is under the control of the municipality, while in New Mexico, the communal system of the Pueblo Indians, and the old Spanish laws, are still recognized.

THE COLORADO LAW.

Of all the States and Territories in the arid region, Colorado is the only one that has a well defined and comprehensive code of laws relating to irrigation. The riparian doctrine is not recognized in that State, and the Legislature has decreed that all the waters of its streams and lakes belong to the people, and are subject to appropriation for irrigation, mining or other useful purposes. In 1881 a law was passed providing for the "proving up" and recording of water-right claims, and for the administration of the waters of streams and lakes. It provides that every claimant by appropriation, shall file with the County Clerk a statement of the nature, extent and history of his claim, and further provides that such statement shall be published for a stated period. It next makes provision for a judicial inquiry into the status of the various claims. The dates and extent of the appropriations, and the construction and enlargement of canals, are required to be proved before a court referee. The referee is required to make findings of facts concerning all the water claims in the district brought to his notice, and report them, with the evidence, to the court having jurisdiction. The court then gives all parties a hearing, and is authorized to enter decrees declaring the extent and priority of each claim; and such decrees form the basis for the future distribution of the waters of the streams to the canals.

The State is divided into water districts, with a water commissioner in each, whose duty it is to regulate the distribution of the waters, decide disputes between appropriators

subject to appeal to the courts, and exercise general supervision over the natural and artificial waterways of his district. In times of scarcity he divides the waters among the several canals according to the prior rights of each. The State Engineer has entire supervision of the public waters of the State. He is required to make accurate measurements of the volume of water in the streams of each district. This measurement will show the commissioners the quantity available at any time for irrigation purposes. By the system of correct measurement the irrigator is assured that when he purchases a water right from a canal company he will get the value of his money, as corporations are not allowed, as in other irrigating countries, to sell more than they are entitled to receive from the stream. The State furnishes the expert service to keep measurement of the waters in the streams and gauge the canals and head-gates, upon which data and the decrees and the renewed or extended claims made from time to time, the water commissioners act in their distribution work.

This is an outline of the law now in force in twenty-four water districts of the State, and which is giving general satisfaction. It is a strict account-keeping of the waters available for diversion, in which the State regulates the distribution according to the decreed rights of each appropriator. Since the law went into effect, there has been an almost entire absence of litigation; and with such a system based upon equity and common sense, the agricultural area of the State is being steadily enlarged.

The foregoing brief outline will show how loose, vague and undetermined are the laws relating to water in the arid regions of the United States. It also shows the imperative necessity for more perfect legislation on this, the most vital of questions to the people of the great interior basin. Outside of Colorado, no State or Territory within this vast domain has made an effort to grapple with this important problem. The necessity for legislative supervision, and for a clear and comprehensive system of legal supervision, is apparent to all. Vast interests are at stake which are increasing year by year. The growth and future prosperity of an inland empire depends, mainly, upon wise and equitable laws controlling and regulating its water supply. From an agricultural point of view, the wealth of the rainless region is in its streams and lakes; and the proper application of their waters to the thirsty soil, is a question of existence for millions yet to come. The control of this precious element is rapidly passing into the hands of speculators, while the governing power makes no effort to prevent the abuse and monopoly which is every day growing greater. If the land is the birthright of the people, how much more so is the water to the inhabitants of the dry belt—their very existence depends upon it.

The Governor of the State of California has called attention to the unsettled condition of the water question in that commonwealth. He has pointed out the magnitude of the interests involved, the vested rights that have accrued, and the necessity for legislative enactments that will set at rest the disputes and litigation about water rights. The last session of the legislature was devoted mainly to this question, and a law modeled after that of Colorado, was presented but failed to pass. The advocates of the riparian doctrine strongly opposed the measure, and set their faces against any compromise with those who favored "appropriation." But if California expects to prosper, she must, once for all, abandon the riparian idea. Its enforcement would virtually paralyze every industry in two-thirds of the State, and would be a death blow to its growth and advancement.

PROPOSED CALIFORNIA LAW.

The necessity for State control was ably set forth by Mr. Hall, State Engineer, at the convention of irrigators held at Riverside, in May, 1884. There is no man on the Coast who has given to the subject more careful study, or whose opinions are entitled to more weight. In his address before that gathering, Mr. Hall declared that in countries where irrigation was long practiced, it was shown that it must be carried on in conformity with a well-defined administrative system, if the larger percentage of possible results are to be obtained. Thus far, the policy of California has been to leave the distribution of the

public waters to the claimants thereof, and the settlement of disputes to the courts. With equal propriety, the general government might throw open the public domain to appropriation, do away with land offices, and require no proof of claims except when disputed in court by some rival claimant. Of course, under such a system (?) there would be no undisturbed titles in land. And yet this is the policy, not only of California but of nearly all the irrigating States and Territories in the Union. The fundamental principles of irrigation never have been, and never can be solved by the policy of non-intervention.

Mr. Hall proposed as a solution of the irrigation problem in California, that the State shall assume control over the waters, and direct and supervise their division from the streams:

That all existing water privileges should be defined and recorded: —

That a definite standard of measurement for water should be established:

That water rights should be issued in proportion to the supply in each stream, and that the extent and priority of each claim should be designated:

That provision should be made for supervising the distribution of water from the streams or sources of supply, to those holding water rights:

That provision should be made for the care of the beds, the banks, and the waters of the streams:

That the adjustment of the conflicting interests of the irrigator and the riparian claimant should be provided for as they arise:

That general regulations should be established from time to time, which will prevent waste, and guard against water monopolies and the careless use of the fluid.

This plan contemplates State regulation of the sources of supply, and of the waters allotted to each claimant. It also provides for private regulation, under State laws, of the details of distribution from the canals to the irrigator; and State regulation of the use of water, to the end that none may be wasted. The State is likewise given power to adjust conflicting rights by arbitration, when possible, or by condemnation, when necessary or possible.

Mr. Hall urged that this plan would not be an attack on any interest, but would bring protection to all. The appropriators would have their rights definitely defined, and would have to prove their claims according to accurate measurements and reliable evidence. When the *facts* of all claims were made of record, there would be a relief from future litigation, and there would be no obstacle to the acquirement of future rights, under well-defined and equitable regulations. The facts concerning water rights should be as easily ascertained as the history of land titles, yet in Southern California to-day, they are uncertain and undetermined, and are left for adjustment by piece-meal as individual cases come up, which adjustments are merely make-shifts for the time being.

WATER MONOPOLIES.

The matter of the corporate control of water was fully discussed by the Riverside Convention. The necessity for organized capital in the construction of large irrigating works was admitted, and the great benefits it conferred was acknowledged. But the importance of State supervision of such enterprises, was clearly pointed out. Railroad, gas and telegraph companies, were all subject to legitimate competition, but in supplying water Nature has, in most instances, prevented competition by rival corporations, by limiting the supply. This was urged as an unanswerable argument in favor of State control; for a monopoly of water in regions where the article was scarce, would place the property of the people in the hands of a corporation, subject to its arbitrary action. Water, being a "public use," no company or corporation had a right to any property in it; they were entitled to a remuneration for conveying it upon the land and distributing it, no more. The Convention believed that the enforcement of the law giving the boards of supervisors the power to fix rates, should be just alike to the corporation and the irrigator—aiming to give the former fair interest on the investment, but preventing it from overcharging or changing established rates.

But while the meeting at Riverside was strongly in favor of equitable laws for the control of "the chartered collectors of water taxes," it was equally strong in its condemnation of the extravagant and criminal waste by claimants to water rights who, under the assumption of priority of appropriation, wilfully wasted water while the crops of their neighbors were suffering for its use. As one member pertinently remarked, "if a corporation is to come under the ban of the law for bringing water upon land and distributing it, why are other appropriators permitted to uselessly squander it?" It was admitted that if the State had the right to exercise control over private enterprises dealing with an elemental property and a natural source of wealth, it had also the right to prevent its criminal waste. It is a well-settled law in the old irrigating countries that land and water should be "married," and that land titles should include water also. The California irrigators endorsed this doctrine, and resolved that both should be "wedded, sold and held together," and, that after once being united, they should never be separated.

The Convention condemned the riparian doctrine as detrimental to the best interests of the State; declared there could be no more property in water than in air, and that no one should have a monopoly of that which was owned by all, and unanimously recommended the passage of a law similar to that of Colorado.

VIEWS OF MR. DEAKIN.

In closing this paper it may not be amiss to present the views of Hon. Alfred Deakin, of Australia, on this question. Mr. Deakin was commissioned by the Government of the Victoria colony to make a thorough examination of the system of irrigation practiced in Western America. After digesting the facts which came under his observation, he submitted the following outline for an irrigation law in Victoria:

"The State should exercise supreme control over rivers, lakes, and streams.

"It should dispose of water to those who may require it for irrigation, on such terms and conditions as may be determined by regularly qualified officers.

"It should establish a definite scale of water measurement in all transactions relating to its use.

"The State should appoint local water masters to supervise its distribution, settle disputes, and exercise such jurisdiction, under a central office, as shall guarantee preservation of water-courses, and other sources of supply."

It will thus be seen that the concurrent opinion of those who have made the irrigation question a study is in favor of State control and supervision. In no other way can the best results be obtained, and by no other method can security and protection be assured alike to private rights and public enterprises.



METHOD OF IRRIGATION.

THE method of conveying water to trees, plants, and cereals is an art to be learned only by experience. A thorough knowledge of conducting the life-giving fluid over the land means a saving in its use, better cultivation, and an increased production. The system varies with the diverse conditions of different countries, from the primitive water-wheel of the Egyptian peasant to the sub-irrigation pipes of Southern California. The earliest, the simplest, and the cheapest method is by "flooding." By this plan the

water is made to cover the whole area under tillage, to the required depth. From the main canal the cultivator conveys the water to his land by lateral ditches. Very often a number of farmers whose holdings lie contiguous, unite in constructing the main "lateral." From this each opens sub-laterals or field ditches, which carry the water to all parts of the farm.

FLOODING.

The plan of "flooding" is the most wasteful manner of applying water to the soil, but it cannot be avoided in the cultivation of cereals. With a regular slope the work is trifling, but in most countries some outlay is required for levelling surface inequalities, and providing for the equal distribution of the stream from points of vantage. When the fall is slight, shallow ditches are run from fifty to one hundred feet apart in the direction of the slope; when the land is steeper they are carried diagonally to the slope or made to wind around it, and from these, by throwing up little dams from point to point, the whole field is flooded. These ridges or dams must have rounded crests and easy slopes, so as not to interfere with the use of farming machinery. By means of diagonal furrows and dams it is claimed that one man can irrigate twenty-five acres in a day. This is the plan which prevails in Colorado for the raising of grain.

In the valleys of Southern Arizona the labor and cost of applying water to the soil is, perhaps, less than in any other region of the irrigated area of Western America. The land is almost as level as a floor, with a gradual slope from the foothills to the streams. The farms are checked off into plats by shallow furrows, into which the water from the sub-laterals finds its way and is quickly conveyed to every part of the field. The process is so simple that an inexperienced hand finds no difficulty in soon mastering the details. It may be said that in "flooding" the aim should be to put no more water on the land than it will at once and equally absorb, or can part with without creating a current that will carry off sediment. Where there is a heavy fall and the water has been allowed to flow too freely, the result has been the washing away of all the fertilizing elements.

BY FURROWS.

Irrigation by means of furrows has been found the most successful for vines and fruit trees, as also for nearly all vegetables. These furrows are generally run from four to ten feet apart, and when the water flows through them it soaks quickly to the roots, whereas by the flooding system the soil is apt to bake if not protected from the sun. When unrestricted flooding is practiced in orchards, it is found to bring the roots to the surface, enfeeble the trees and give to the fruit an insipid taste. Sometimes a small hole is opened in the furrow at the foot of the tree, into which the water slowly soaks. A better way is to surround the tree or shrub by small ridges some three feet from where the water flows. To obtain the best results the trees should be carefully looked after, and supplied with just enough water to keep them in a vigorous condition. It is also of the first importance that the soil be kept loosened. By doing this the water is more readily absorbed and there is less lost by evaporation.

SUB-IRRIGATION.

Irrigation beneath the surface is considered the most perfect method of supplying water to vegetable life. The manner in which this is done in California is thus described by the State Engineer of that commonwealth: "Pipes, made of a combination of Portland cement, lime, sand, and gravel, with a small admixture of potash and linseed oil, are laid at a depth of one and a half or two feet below the surface, paralleled to the rows of trees or vines. On the upper side of these pipes is inserted a wooden plug, with a tapering hole in the center about three-eighths of an inch in diameter, through which the water percolates. Each plug is surrounded by a stand-pipe setting on top of the distribution pipe, open at the bottom and reaching to the surface. This pipe keeps the earth away

from the outlet and leaves it at all times accessible for inspection. The distribution pipes are connected with mains leading from a reservoir, and the labor of irrigation merely consists in turning on the water and shutting it off. The water finds its way through all the outlets and slowly reaches the roots. None is carried on the surface, consequently the ground does not bake, but is kept moist and mellow. In the orchard of the inventor of this system, three acres of fruit were irrigated within half an hour. Water applied twice a month is sufficient to maintain a strong and healthy growth; and the trees attain twice the size of others of the same age and in the same soil, irrigated from the surface. By this system it is estimated that a cubic foot of water will be sufficient to supply from 7,000 to 9,000 acres. Three men can lay 1,600 feet of pipe per day—the cost of the work completed, being from \$30 to \$50 per acre.” Where water is scarce and high priced fruits are cultivated, this method is fast superseding the old surface system.

BY PUMPING.

Irrigation of vineyards and orchards by lifting water from various depths, has long been practiced in California. The motive power, in many cases, is supplied by windmills. These cover but a limited area, but several orchardists have adopted steam power which pump water for extensive tracts. A leading fruit-grower of the southern part of the State, who depends entirely upon this method for the raising of a crop, furnishes the following data: “With a six-inch pump, driven by a twenty horse-power engine, I have raised 1,800 gallons per minute. The price of such a pump, including engine, boiler and all steam fittings, is \$1,400. To cover an acre of land one inch deep with water, requires, in round numbers, 23,000 gallons. One miner’s inch being nine gallons nearly, it would require to cover 21 acres one inch deep, 2,555 inches, or 480,000 gallons. A No. 4 turbine pump will raise in a day’s run of ten hours, 480,000 gallons. This would be at the rate of 800 gallons or 80 miner’s inches per minute. The total cost of running such a pump, including fuel and wages, will not be over \$5 for each working day of ten hours, which would make the cost of placing the 480,000 gallons on the land, about one cent per 1,000 gallons. This from a depth of 25 feet. To raise the same quantity of water from a depth of 80 feet would cost about \$7, or $1\frac{1}{2}$ cents per 1,000 gallons.” This system of lifting water for irrigating purposes, is meeting with great favor in many quarters where there is a scarcity of the fluid, or where canal corporations charge exorbitant rates.

Irrigation from artesian wells is practiced extensively in Southern California. The number in Los Angeles County is estimated at 500. The flow from most of them is variable; and while some will supply 100 acres, from 40 to 50 is the general average. It is claimed that over 18,000 acres are cultivated by this method in that county.

IRRIGATION AS A FERTILIZER.

The fertilization of the land by irrigation varies according to the nature and quantity of the silty matter which the water brings upon it. The estimate of this gain by cultivators is from 30 to 100 per cent. There seems to be no products of which the yield may not be increased by irrigation, as there are none that will not be diminished by excessive saturation. The latter acts upon the crop exactly as would too much rain. Careful irrigation brings to the farm, vineyard, or orchard, a steady fertilization which renders any further enrichment of the soil unnecessary.

The mistake with all beginners is the using of too much water. The irrigator must see that his work is done carefully and thoroughly; looking after every stream, wetting every inch of the soil, and copying, as nearly as possible, after nature.

IRRIGATION IN ARIZONA.

ARIZONA is one of the oldest of irrigated countries. When the Spaniards explored the regions now embraced within this Territory and New Mexico, they found this system of agriculture practiced by the Pueblo and other semi-civilized Indian tribes. But the traces of irrigating canals in the valleys of the principal streams, would show that this method of cultivation was carried on here centuries before Europeans set foot on the Western Hemisphere.

The Pimas are the earliest irrigators in the Territory of whom we have any authentic account. When Coronado led his expedition through Arizona, in 1540, these people were found farming the lands of the Gila Valley by the aid of primitive irrigating ditches, just as they do to-day. The communal system of land and water prevailed amongst them as it does now; and the centuries which have since come and gone have brought no changes to the Pima nation. They still till the soil and gather the harvests as their forefathers did, and as their descendants will, no doubt, continue to do, until the last of the race shall have been gathered to the happy hunting grounds.

The Mission Fathers were the first to introduce a more perfect system of irrigation in the region now known as Arizona. The neophytes who gathered around their religious establishments in the valley of the Santa Cruz, were instructed by the pious *padres* in the arts of tillage, and taught to build ditches and raise crops on the rich bottom lands of that stream. For years the settlements on the Santa Cruz represented the extent of agricultural effort in Arizona; and it was not until the Americans established themselves in the valleys of the Salt and Gila Rivers that this method of farming was practiced to any extent in the Territory. Since that time, now nearly eighteen years ago, the irrigable area has steadily enlarged, and within the past year several important canal enterprises have been inaugurated.

The agricultural resources of the country, so long neglected, are attracting the attention of people abroad, and the question of water supply is of the first importance to the new-comer. And, in passing, it may be remarked that our knowledge of this matter, is most vague, indefinite, and altogether unreliable. It is nearly impossible to secure data in which any reliance can be placed. Men who for years have practiced irrigation in this Territory seem to be incapable of giving intelligent answers to any question relating to the business. They know they have plenty of water and the privilege of using it when they please, but beyond this they have not cared to enquire. As a consequence, the facts relating to the irrigation problem in Arizona are difficult to obtain. The information presented falls far short of what the writer sought; but repeated enquiries to farming settlements, in different parts of the Territory, have failed to elicit a response.

CAPACITY AND COST OF CANALS.

The Salt River Valley has the largest and most costly irrigating works which Arizona can show. The names of the leading waterways, and the length of each is as follows:

Arizona Canal.....	40 miles.
Grand Canal.....	22 "
Maricopa Canal.....	14 "
Salt River Valley Canal.....	18 "
San Francisco Canal.....	9 "
Tempe Canal, length (estimated).....	18 "
Mesa Canal.....	9 "
Utah Canal.....	6 "
Farmer's Canal.....	5 "

Total Length of Canals.....151 miles.

There are a number of smaller ditches scattered over the valley not included in the above, which may increase the total length to one hundred and sixty miles.

The cost of these canals is hard to determine. Aside from the first outlay for construction, there is to be considered the yearly repairs for breakage of dams, enlargement of ditch, etc. The figures on some canals could not be obtained.

Arizona Canal (estimated) cost.....	\$400,000
Grand Canal.....	40,000
Maricopa Canal.....	25,000
Salt River Valley Canal..	40,000
San Francisco Canal.....	20,000
Tempe Canal (estimated)..	50,000
Mesa Canal (estimated)..	40,000
Utah Canal (estimated)..	15,000
Farmer's Canal (estimated) "	6,000
Total.....	\$636,000

It is quite likely that these figures are much too low, and that the actual cost of the irrigating ditches in the valley will not fall short of \$800,000. The carrying capacity of the several canals, as nearly as can be ascertained, is as follows:

Arizona Canal.....	40,000 inches.
Grand ".....	10,000 "
Salt River and Maricopa Canals.....	6,000 "
San Francisco Canal.....	4,000 "
Tempe ".....	6,000 "
Mesa ".....	4,000 "
Utah ".....	2,000 "
Farmer's ".....	500 "
Total.....	72,500 inches.

Of this volume of water little more than 25,000 inches is now being carried upon the land and utilized. The area reclaimed in the valley by the various canals now constructed, is not easily ascertained, but the following approximate estimate will not vary materially, from the actual figures:

Arizona Canal.....	85,000 acres.
Grand ".....	20,000 "
Maricopa ".....	12,000 "
Salt River Valley Canal.....	15,000 "
San Francisco ".....	6,000 "
Tempe ".....	15,000 "
Mesa ".....	10,000 "
Utah ".....	4,000 "
Farmer's ".....	1,000 "
Total.....	168,000 acres.

This is something like the area enclosed, and which could be watered by the present canals. It may be that some of these ditches have not a carrying capacity at present, sufficient to irrigate the acreage they enclose, but all the land which naturally lies under them, will, no doubt, yet be reclaimed by their waters. Of this large acreage, it is believed that not over 40,000 or less than one-fourth of the whole, is under cultivation. Of the 400,000 acres of surveyed land in the Salt River Valley, it is believed that 250,000 are susceptible of irrigation. When people learn to use water with that care and economy that is practiced in countries where scarcity makes it precious, there is hardly a doubt that this immense tract will be made productive. At present, but little more than three-fifths of it is enclosed by canals, and less than one-sixth is under cultivation.

The *Pueblo Viejo* Valley, on the upper Gila, is one of the richest tracts of agricultural land in the Territory. The following ditches have been constructed in that valley:

San Jose; seven miles long; reclaims 2,000 acres; cost \$5,000.

Montezuma; thirteen miles long; reclaims 5,000 acres; cost \$8,000.

Sunflower; three miles long; reclaims 500 acres; cost \$2,500.

Central; eight miles long; reclaims 5,000 acres; cost \$7,000.

Smithville; five miles long; reclaims 3,000 acres; cost \$4,000.

Nevada; three miles long; reclaims 500 acres.

McMurrin; four miles long; reclaims 600 acres.

These ditches are on the south side of the Gila. On the north side of the river there are six, aggregating twenty-three miles in length and reclaiming about 3,000 acres. Their total cost was near \$12,000.

This shows the total length of irrigating ditches in the *Pueblo Viejo* to be sixty-six miles.

Cost of Same.....	\$43,000
Land Reclaimed.....	19,600 acres

Of this area, not more than 12,000 acres are now under cultivation. The capacity of the several canals was not given. The total acreage of arable land in the valley is nearly 40,000; so that less than half of it is enclosed.

The largest body of arable land in Yavapai County is found in the Verde Valley. There are, besides, a number of small valleys in different parts of the county, where irrigation is practiced, but the area under cultivation is small, owing to the limited water supply. Hon. John Davis, an old resident of the Verde, sends the following figures about irrigation in that locality:

Nine canals have been constructed, aggregating about 30 miles in length, and costing about \$20,000. These canals supply water to 2,000 acres—their united capacity being about 1,500 miner's inches.

No data in regard to the condition of irrigation in Pinal, Apache, Pima, or Yuma Counties, has been received. There are a number of canals in the valley of the Gila, near Florence, and fully 10,000 acres are under cultivation in that neighborhood. On the Little Colorado and its tributaries, in Apache County, it is estimated there are close on to 18,000 acres reclaimed, most of which is under cultivation. In Pima County there is said to be 4,000 acres under the plow, and in the valley of the San Pedro, Cochise County, about the same number. In Yuma County there is said to be 2,000 acres cultivated. Estimating the cost per acre for reclamation in those counties at \$4, which is a low figure, the outlay for canals in each would be as follows: Pinal, \$40,000; Apache, \$72,000; Pima, \$16,000; Cochise, \$16,000; Yuma, \$8,000. This would make the total cost of the irrigating works already constructed in Arizona, over \$1,000,000. The total length of all these waterways cannot be much less than 400 miles.

"DUTY" OF WATER.

The "duty" of water in Arizona may be considered an unknown quantity. There is but little data relating to the question worthy of any consideration. The loose and unreliable system of measurements which prevail, make any definite calculation almost impossible. The practice, which very generally exists, of taking water at pleasure in such quantities as may be desired, makes the irrigator altogether indifferent to the matter of measuring it. While all the larger canals employ a *zanjero*, whose duty it is to make an equitable distribution according to the "rights" of each cultivator, yet, so loosely is the business conducted, that very often one man receives much more than he is entitled to, while another receives much less. Throughout the irrigated valleys of the Territory, water is measured by the miner's inch, generally with a four-inch pressure. It has been shown how inaccurate is this standard, and how variable are the results from it.

Taking the Salt River Valley as an example of the system of artificial cultivation which prevails in the Territory, we find that all the principal canals are owned and managed by incorporated companies. With the exception of the Arizona Canal, all those ditches were constructed by the co-operative efforts of the owners of the land which has been reclaimed by their waters. Some furnished teams and tools, others gave their labor, while a few contributed a money consideration. Stock was issued to each according to the amount of money or labor he gave to the construction. This was the origin of the system of "water rights" which prevails throughout the Territory. The first cost of each "right," or share,

was the amount of money or value of labor which the owner contributed to the building of the works, but there has been a rapid increase in value. In all of these canals, each share of stock represents a quantity of water supposed to be sufficient for the irrigation of a quarter section of land. This "right" is generally 80 miner's inches. The owner of a share of stock has the privilege of drawing from the canal, each season, the quantity of water which it represents, by paying therefor a certain price per inch. If he does not wish to use the water himself, he can sell his privilege, for the season, to whom he pleases. And, again, if this share of stock entitles him to purchase 80 inches, and he finds that 60 inches is all that he requires, he can sell his right to the remaining 20 inches to whoever applies for it. If the income from the sale of water is not sufficient for the maintenance of the canal and the pay of officers, an assessment is levied upon the stockholders to meet the deficiency; and if there should be a revenue from sale of water to parties not holding shares, a dividend is declared. This is the plan that governs in the Salt River Valley, the Maricopa, and the Grand Canals.

The quantity used per acre under these canals, varies from one-half to three-eighths of an inch, during the irrigating season. Experienced irrigators find the latter quantity abundant to produce a crop. Here, as in all other irrigated regions, it is found that continuous flooding for a number of years, increases the duty of water. Several farmers, south of Phoenix, do not use more than one-quarter of an inch per acre for the production of a crop, and some get along with much less. In the vineyard of Mr. John Montgomery, water is found at a depth of 12 feet below the surface; the roots of the plants have penetrated to the moisture, and he has not irrigated his vines for two years. In the Tempe Canal, which is controlled by a private company, each share-owner takes as much as he requires, and as often as he requires it—there being no measurement and no limit, except the supply in the river. Yet, under this wasteful system, it is found that 60 to 80 inches is enough to produce a crop on 160 acres.

There is an extravagant use of water in the *Pueblo Viejo* Valley. In that locality water is divided into "irrigating streams," each "stream" containing one hundred any forty-four miner's inches, under a four-inch pressure. This body of water is used to irrigate eighty acres during the season. This is, perhaps, the most wasteful use of the fluid that any portion of the arid region can show. In the Verde Valley, the duty of water is three-fourths of an inch to the acre. It is acknowledged that crops could be raised with much less, but as there is an abundance in the stream, each man takes as much as he pleases. The quantity of water used per acre in the farming settlements of Pinal, Cochise, Apache, and Pima will range from one-half to one inch. Wherever irrigation is practiced in the Territory there is waste and extravagance in the use of water. Ignorance and inexperience in the application of it is, in most cases, the main cause. Where the careful cultivator and experienced irrigator finds three-eighths of an inch per acre entirely sufficient, his neighbor, farming the same character of soil and raising the same kind of crops, will not be satisfied with less than an inch to the acre.

COST OF WATER.

The cost of water to the Arizona irrigator is another difficult matter to determine. Water "rights" for the irrigation of a quarter section of land in the Salt River Valley vary from \$500 in the Grand, to \$1,000 in the Arizona Canals. Having secured a "right," the cultivator has then to pay so much, yearly, for the water he requires. In the Grand Canal the price is \$2.00 per inch, in the Maricopa about the same, and in the Salt River Valley Canal \$1.75 per inch. Under the rules adopted by the Arizona Canal Company, the farmer is taxed at the rate of \$1.25 per acre, for every acre he cultivates yearly. It will be seen that this system is radically different from that which prevails not only in Arizona but in nearly all of the irrigated regions of the West. Under the plan adopted by this company, the water is wedded to the land, neither can be sold separately; while in all the other incorporated canals in the valley the reverse prevails, and water shares pass from hand to hand like any other commercial paper. The danger of the latter policy lies in the opportunity it presents for the control of the stock by unscrupulous speculators.

The Arizona Canal Co. issues no stock to purchasers of water rights, and consequently they have no voice in its management or control; while in all the other companies shareholders have a vote and a voice in the regulation of their affairs. Water owners in the Tempe Canal, which is not incorporated, pay nothing, directly, for the use of the water, but are liable to an assessment each year for maintenance of works and pay of officers.

The waters of the canal which supplies Mesa City, are rented to the farmers at the rate of \$30 per share per year—a share being sufficient to irrigate thirty acres—making the cost one dollar an acre. In the distribution of water from the irrigating canals of the Territory there is but one feature worthy of any commendation. That is the policy which has been adopted by the Grand, Maricopa, and Salt River Valley Canals of selling water to those entitled to purchase, in such quantities as the irrigator finds sufficient for the production of a crop. With a correct system of measurements and careful supervision of works, this method is a good one. It encourages the consumer to be economical in the use of water, knowing that he can sell what portion of his "right" he does not use, to some one who wants it. It is the only just and sensible policy, as no one should be compelled to pay for more water than he requires. For water corporations to adopt an opposite policy seems short-sighted. The less water required to cultivate a tract of land, the more water rights the company will be able to dispose of, and the larger the area that will be reclaimed.

TERRITORIAL LAWS.

Arizona, being one of the oldest irrigated regions of the western continent, a stranger would naturally expect to find here a well-matured legal code regulating the control and distribution of its waters. In this he would be disappointed. The water question is in as unsettled a condition here as in California; and while the Territory has thus far escaped the flood of litigation which has swept over the Golden State, an increase of population and a greater demand for water gives warning that it may not be so fortunate in the future. Our bill of rights declares that "all streams, lakes, and ponds are public property," and that no one has the right to appropriate them exclusively to his own private use. The Territorial statutes declare that all rivers, creeks, and streams of running water "are applicable to the purposes of irrigation and mining;" and the further declaration is made that "all the inhabitants of the Territory who own or possess irrigable lands shall have the right to construct public or private *acequias*, and obtain the necessary water for the same from any convenient river, creek, or stream." This is the gist of the Territorial law relating to irrigation. It merely recognizes the right of appropriation, but makes no provision for the proper regulation of the same. Neither does it make any provision for the control, distribution, measurement, or sale of the precious fluid. Individuals or corporations may appropriate and control large quantities of water, but there is no legal supervision over their acts, nor any safeguards thrown around the consumer. There is nothing to prevent criminal waste, nor is there any check to corporate extortion. And yet there is nothing which should be guarded more carefully or prized more dearly. Arizona's mineral wealth has been called "the jewel of her sovereignty," but her rivers and streams are the arteries through which courses her very life blood.

Priority of appropriation has been recognized by our Territorial courts, but where rights are so vaguely defined and appropriation so unrestricted, there must be a lack of that feeling of security which should attach to the possession of water as well as to land, in a country where irrigation is a necessity. The greatest evil that can befall such a country is an insecure and undetermined title to water. In arid regions, like Arizona, the values are entirely in the water, without it the soil must always remain a desert. People seeking homes here realize this fact, and desire, first of all, to know that the supply is abundant, and that the titles are secure. Is it not then of primary importance to every one who has the interest of the Territory at heart to have this matter adjusted on a basis just and equitable to all?

The necessity for wholesome legislative control over the wholesale appropriation of

water, is apparent to every one. Large quantities are being claimed by corporations, and in a short time every inch, available for agriculture, will be appropriated. The possession of the water by those companies, virtually, gives them control of the land. Now, while such reclamation enterprises are of great benefit to the Territory, and worthy of all legitimate encouragement, it is yet the duty of the people of Arizona to see that its public waters are not controlled by monopolies.

The large canals now being constructed in the valleys of the Gila, as well as the Arizona Canal, in the Salt River Valley, are speculative enterprises, out of which their projectors expect to make money. This is proper and entirely legitimate, and those who have engaged in such ventures deserve to be well remunerated. But while favoring every public enterprise of this character, it is the duty of the people to see to it that such corporations do not misuse the powers which the control of large quantities of water naturally gives them. The primary principle that water is a gift from Nature, and as necessary to man's existence as the air he breathes, should not be lost sight of. For the construction of irrigation works and the bringing of water to the cultivator, there should be given a fair and liberal compensation. This is a proposition that will not be disputed. Neither can the right of the people to prevent unjust and extortionate water charges, be denied. If there is no check upon the actions of large canal companies, the farmer and fruit-grower must rely entirely upon their sense of justice. The people of California and Colorado, realizing this danger, have made legal provisions which effectually prevent extortion by water companies.

The loose system of measurements should be done away with, and wastage should be prevented. In a country like ours where every inch of water is precious, reckless waste ought to be made a criminal offence. The present system of claiming thousands of inches of water, which are not used, is untenable both in law and equity. No individual or corporation has a right to any more water than he or they actually use. This is the only true policy, and is recognized in all irrigating countries where the waters are under legislative control.

The waters of all rivers and streams in the Territory which are utilized for irrigation, should be accurately measured, and the quantity available at all seasons should be known. This would not only be of great benefit to the irrigator, but would do away with the present system of unchecked appropriation. When the volume of water in a stream was known, and the share of each appropriator definitely determined, it would assure to the farmer a certainty that the water company would be able to deliver the quantity he contracted for.

Irrigation to Arizona is what the life blood is to man, or the piston rod to the steam engine. The just and equitable control and distribution of the public waters of the Territory assure to our fertile valleys a large and permanent population and a prosperous future. It is a vital question to our people, and one which heretofore has received but little consideration. Yet it is not too much to say that the corner stone of Arizona's prosperity rests upon it. How important, then, is it to the general welfare that our irrigation system should be upon a secure foundation of equity and justice, preserving for all their rights in one of the most precious gifts of Nature, and doing no wrong to vested interests.

It is for those directly interested, and with the light of experience to guide them, to decide how this important problem shall be solved. It is a matter deserving of more thought and attention than has yet been bestowed upon it. Its satisfactory solution is only a matter of time; but it would be well if the people of these valleys would consider the question from a broader and more liberal standpoint than that of mere self-interest. It is admitted that law of some kind is a necessity, but what particular laws a people should have on any particular subject, is for the people themselves to decide. In conclusion, it may be said that these papers have been collated and published with the hope that they may prove of some benefit to the Arizona farmer. If the data contained therein shall help him to a better understanding of the irrigation question, and if a knowledge of the laws and regulations governing it in other countries shall assist him to deal intelligently with it here at home, the effort will not have been in vain.



